

(English Translation of Japanese Patent Application No.2004-034778)

METHOD OF PRODUCING A SPREAD MULTI-FILAMENT BUNDLE AND AN APPARATUS USED IN THE SAME

WHAT IS CLAIMED IS:

1. Method of producing a spread multi-filament bundle comprising the steps of: feeding a multi-filament bundle from a yarn supplier such as bobbin, cheese and cone with a restraint of said multi-filament bundle being drawn back; subjecting said multi-filament bundle to fluctuation of a tensile force applied to said bundle alternatively and intermittently between tension and relaxation; passing said multi-filament bundle moving under said fluctuation through a fluid flowing portion disposed along a moving course of said multi-filament bundle with said multi-filament bundle supported in suspension on said fluid flowing portion to put a fluid into contact with said multi-filament in passage so as to bend said bundle towards a direction to which said fluid flows with said fluid flowed through adjacent monofilaments of said bundle, thereby, said multi-filament bundle being widely spread so as to be produced into a spread multi-filament bundle.

2. Method of producing a spread multi-filament bundle comprising the steps of: feeding a number of multi-filament bundles from a creel provided with a number of yarn suppliers such as bobbin, cheese and cone with a restraint of said multi-filament bundles respectively being drawn back; subjecting said respective multi-filament bundles to fluctuation of a tensile force applied to said respective multi-filament bundles alternatively and intermittently between tension and relaxation; passing said respective multi-filament bundles moving under said fluctuation through a fluid flowing portion disposed along a moving course of said respective multi-filament bundles with said respective multi-filament bundles supported in suspension on said fluid flowing portion to put a fluid into contact with said respective multi-filament bundles in passage so as to bend said respective

multi-filament bundles towards a direction to which said fluid flows, thereby, said respective multi-filament bundles being widely spread so as to be produced into respective spread multi-filament bundles.

3. Method of producing a spread multi-filament bundle comprising the steps of: feeding a number of multi-filament bundles from a creel provided with a number of yarn suppliers such as bobbin, cheese and cone with a restraint of said multi-filament bundles respectively being drawn back; subjecting said respective multi-filament bundles to fluctuation of a tensile force applied to said respective multi-filament bundles alternatively and intermittently between tension and relaxation; passing said respective multi-filaments bundles moving under said fluctuation through a fluid flowing portion disposed along a moving course of said respective multi-filament bundles with said respective multi-filament bundles supported in suspension on said fluid flowing portion to put a fluid into contact with said respective multi-filament bundles so as to bend said respective multi-filament bundles towards a direction to which said fluid flows, thereby, said respective multi-filament bundles being widely spread so as to be produced into a spread multi-filament bundles sheet with adjacent monofilaments of said respective multi-filament bundles tangentially aligned.

4. Method of producing a spread multi-filament bundle in any one of the preceding claims wherein a spread multi-filament bundle discharged from said fluid flowing portion is subjected to a back-and-forth friction widthwise with regard to said bundle so as to uniformly distribute a number of filaments comprising said bundle in density.

5. Method of producing a spread multi-filament bundle comprising the steps of: feeding a number of multi-filament bundles from a creel provided with a number of yarn suppliers such as bobbin, cheese and cone with a restraint of said multi-filament bundles respectively being drawn back; subjecting said respective multi-filament bundles as fed to

fluctuation of a tensile force applied to said respective multi-filament bundles alternatively and intermittently between tension and relaxation; overlapping one over another or disposing side by side respective spread multi-filament bundles as produced by putting a fluid into contact with said respective multi-filament bundles moving under said fluctuation through a fluid flowing portion disposed along a moving course of said respective multi-filament bundles; subjecting said spread multi-filament bundles as overlapped or disposed side by side to a back-and-forth friction widthwise with regard to said respective spread multi-filament bundles, thereby, said respective spread multi-filament bundles being intermingled with each other so as to be produced into a spread multi-filament bundles sheet whose monofilaments are uniformly distributed in density.

6. Method of producing a spread multi-filament bundle in any one of the preceding claims wherein said multi-filament bundle is locally and reciprocally pressed crosswise with regard to a moving course of said bundle so as to fluctuate a tensile force applied to said bundle in carriage alternatively and intermittently between tension and relaxation.

7. A method of producing a spread multi-filament bundle in any one of the preceding claims wherein a plurality of fluid flowing portions are provided along a moving course of said bundle and said bundle is passed through said fluid flowing portions in succession so as to spread said bundle in a progressive manner.

8. Method of producing a spread multi-filament bundle in any one of the preceding claims wherein said bundle is put into contact with a fluid while passed under a bending degree secure roller disposed widthwise with regard to a moving course of said bundle in said fluid flowing portions respectively so as to maintain a predetermined degree by which said bundle bends in such a manner that a minimum degree by which said bundle moving through said respective fluid flowing portions bends does not become smaller than said predetermined level.

9. Method of producing a spread multi-filament bundle in any

one of the preceding claims wherein a multi-filament bundle whose monofilaments are bonded together with a resin based sizing agent is moved through said respective fluid flowing portions with said bundle heated so as to soften said sizing agent, thereby, said bundle being widely spread.

10. Method of producing a spread multi-filament bundle in any one of the preceding claims wherein a prolonged aperture opened along said moving course of said bundle is segmented into said respective fluid flowing portions with an interval, through which portions said bundle passes in succession so as to be widely spread in a progressive manner.

11. Method of producing a spread multi-filament bundle in any one of the preceding claims wherein said fluid used in said respective fluid flowing portions is suction air stream.

12. Apparatus for producing a spread multi-filament bundle comprising: a yarn supplier such as bobbin, cheese and cone around which a multi-filament bundle is wound; a uni-directional supply mechanism to unwind said multi-filament bundle from said supplier under a certain tension and feed said bundle with a restraint of said bundle being drawn back; a fluid flowing spreader comprising a fluid flowing portion disposed along a moving course of said bundle as fed to put a fluid into contact with said bundle crosswise with regard to said moving course of said bundle with said bundle in carriage supported in suspension on said fluid flowing portion so as to spread said bundle with said bundle bent towards a direction to which said fluid flows and a tensile force fluctuation provider to fluctuate a tensile force applied to said bundle in carriage alternatively between tension and relaxation.

13. An apparatus for producing a spread multi-filament bundle comprising: a creel provided with a number of yarn suppliers such as bobbin, cheese and cone around which a multi-filament bundle is wound; a uni-directional supply mechanism to unwind respective multi-filament bundles from said respective yarn suppliers under a certain tension and feed said respective bundles with a restraint of said respective multi-filament

bundles being drawn back; a fluid flowing spreader comprising a fluid flowing portion disposed along a moving course of said respective multi-filament bundles as fed to put a fluid into contact with said respective bundles in passage crosswise with regard to said moving course of said respective multi-filament bundles so as to spread said respective bundles with said respective bundles bent towards a direction to which said fluid flows; and a tensile force fluctuation provider to fluctuate a tensile force applied to said respective bundles in carriage alternatively between tension and relaxation.

14. Apparatus for producing a spread multi-filament bundle according to claim 12 or claim 13 wherein said tensile force fluctuation provider includes a prolonged rod member laid crosswise with regard to said moving course of said bundle to locally and reciprocally press said bundle in carriage.

15. Apparatus for producing a spread multi-filament bundle in any one of claims 12 to 14 wherein the spread multi-filament bundle passed through said fluid flowing portion is subjected to linearly back-and-forth friction widthwise with regard to said moving course of said spread bundle so as to uniformly distribute monofilaments of said bundle in density.

16. Apparatus for producing a spread multi-filament bundle in any one of claim 12 to claim 15 wherein a prolonged aperture opened along said moving course of said bundle is segmented into said respective fluid flowing portions of said fluid flowing spreader.

17. Apparatus for producing a spread multi-filament bundle in any one of claim 12 to claim 16 wherein said fluid flowing spreader comprises respective fluid flowing portions provided with an air suction portion opened in the same plane along said moving course of said bundle; and a suction pump engaged to a discharge side of said respective fluid flowing portions.

(DETAILED DESCRIPTION OF THE INVENTION)

(TECHNICAL FIELD)

(0001)

The invention relates to spreading a multi-filament bundle,

in more details, pertaining to a method of producing a spread multi-filament bundle and an apparatus used in the same wherein a number of multi-filaments bundles as desired are widely spread with efficiency with a tensile force applied to the respective multi-filament bundles and a direction to which a fluid flows and a flow rate at which the fluid flows in control so as to produce high-quality spread multi-filament bundles and a high-quality spread multi-filament bundles sheet.

(PRIOR ART)

(0002)

Complex reinforced fiber materials comprising such a reinforced fiber as carbon fiber, glass fiber and aramid fiber and a matrix material such as epoxy resin are light in weight and superb in mechanical properties and anti-erosion, so that they are adopted in a wide area for the production of such products as a fishing rod and a golf rod and parts of machine tools as well as for the assembly parts of an airplane. In order to mold such complex reinforced fiber material into a shape, an intermediary material called a pre-impregnation sheet is put to use, in which such matrix resin is impregnated between the monofilaments of a reinforced fibers bundle. In accordance with the recent demand that the weight of such products and parts be further reduced, such pre-impregnation sheet as its monofilaments being uniformly distributed in density and smaller in thickness is sought after.

(0003)

The use of such pre-impregnation sheet as its monofilaments being uniformly distributed and smaller in thickness is intended not only for obtaining a molded article smaller in thickness, but also for allowing for various designs of molding an article taking advantage of the anisotropic characteristics of a reinforced fibers bundle material whose monofilaments are uni-directionally aligned with each other as well as for improving the rupture strength of a molded article in which pre-impregnation sheets are laminated one over another, which it is expected further widens an area for use of the complex

reinforced material. A novel technique for spreading a reinforced fibers bundle is required for obtaining such pre-impregnation sheet as its monofilaments being uniformly distributed in density and smaller in thickness.

(0004)

When a reinforced fibers bundle is spread for the production of a pre-impregnation sheet, it also requires that the material cost be reduced. It is general that a reinforced fibers bundle whose monofilaments are smaller in number is uni-directionally aligned with each other for the production of a pre-impregnation sheet whose monofilaments are uniformly distributed and smaller in thickness. However, such reinforced fibers bundle as mentioned above is expensive, so that it is desirable to use a reinforced fibers bundle whose monofilaments are larger in number. Thus, it requires that a reinforced fibers bundle whose monofilaments are larger in number is spread so as to be formed into a spread reinforced fibers bundle sheet or a pre-impregnation sheet, which makes it possible to obtain such pre-impregnation sheet as its monofilaments being uniformly distributed in density and smaller in thickness with a reduced production cost.

(0005)

Conventionally, such methods of spreading a fibers bundle are known as the fibers bundle being rubbed with a circular rod, its monofilaments being separated from each other by subjecting the same to water flow or high-pressurized air stream, and ultrasonically vibrating its monofilaments so as to be separated from each other. Taking some examples of a circular rod, it is disclosed in Japanese Patent Application Laid-open No.56-43435 that the fibers bundle is passed through a rotating roller which vibrates in the axial direction thereof so as to be spread and it is disclosed in Japanese Patent Application After-grant Laid-open No.3-31823 that the fibers bundle is passed through a plurality of rollers that are disposed in displacement by  $30^{\circ}$  to  $90^{\circ}$  so as to be spread. Taking some examples of water flow and high-pressurized air stream, it is

disclosed in Japanese Patent Application Laid-open No.52-151362 that the fibers bundle is subjected to high-pressurized fluid so as to be spread and it is disclosed in Japanese Patent Application Laid-open No.57-77342 that the fibers bundle is subjected to fluid flowing crosswise with regard to the moving course of the bundle so as to be spread by fluidal dispersion force. Taking an example of ultrasonically spreading the fibers bundle, it is disclosed in Japanese Patent Application Laid-open No.1-282362 that the bundle is put into contact with a circular rod ultrasonically vibrating in the axial direction thereof so as to be spread.  
(0006)

However, any one of the above methods is intended for enforcedly moving the fibers bundle inclined to become converged by a physical force so as to be widely spread while pulling up the fibers bundle along a moving course thereof. Thus, on behalf of the same being spread, the monofilaments thereof are damaged, fluffed and cut in operation. The enhancement of the moving speed of the fibers bundle causes the friction between the circular rod with which the fibers bundle is rubbed and the fibers bundle to enlarge so as to more vulnerably cut the monofilaments thereof while in case of the fibers bundle being spread by water flow, it requires energy large enough to dry up the water contents from a spread bundle. It is hard to widely spread the fibers bundle in a continuous and stable manner with a higher feeding speed thereof, an effective way to cope with which is not yet established.

(0007)

On the background of the above, the subject inventors have proposed an invention entitled 'Method of producing a spread fibers sheet and an apparatus used in the same', which is registered under Japanese Patent No.3049225 and an invention entitled 'Method of producing a spread multi-filament sheet and an apparatus used in the same', which is registered under Japanese Patent No.3064019 wherein the fibers bundle is subjected to an air stream crosswise with regard to a moving



course of the bundle with the fibers bundle flexibly bent so as to be produced into a widely spread fibers bundle whose monofilaments are uniformly distributed in density. Such flexibly bent fibers bundle allows the respective monofilaments thereof to move widthwise with regard to the moving course thereof without enforcement or facilitates each of them to be spread widthwise with regard thereto, the fibers bundle in which condition is subjected to an air stream so as to flow the air through any adjacent monofilaments thereof, thereby, a widely spread fibers sheet being produced, the monofilaments of which are uniformly distributed in density.

(0008)

However, in order to put the above method into realization, a spreading system in one unit comprising a front feeder, a suction cavity tube, a back feeder, a bending degree sensor and so forth is required. Provided that the fibers bundle is more uniformly distributed and more widely and thinly spread, it requires that such spreading system be disposed in series in a consecutive manner so as to be spreading operation gradually performed on the bundle, which makes an apparatus used in the same larger in scale. Further, provided that a number of fibers bundles are lined side by side so as to be spreading operation simultaneously performed on the respective bundles, it requires that the required number of such spreading system be disposed side by side, which makes an apparatus by far larger in scale and more complicated.

(Reference Document 1) Refer to Japanese Patent Application Laid-open No.56-43435

(Reference Document 2) Refer to Japanese Patent Application After-grant Laid-open No.3-31823

(Reference Document 3) Refer to Japanese Patent Application Laid-open No.52-151362

(Reference Document 4) Refer to Japanese Patent Application Laid-open No.57-77342

(Reference Document 5) Refer to Japanese Patent Application Laid-open No.1-282362

(Reference Document 6) Refer to Japanese Patent No.3049225

(Reference Document 7) Refer to Japanese Patent No.3064019

(DISCLOSURE OF THE INVENTION)

(ISSUES TO BE SOLVED)

(0009)

In view of the above inconveniences encountered with the prior art, the invention is to provide a method of producing with facility and high efficiency the arbitrary number of widely spread fibers bundles whose monofilaments are uniformly distributed in density and free from fluffs and an apparatus used in the same method.

(0010)

(MEANS TO SOLVE THE ISSUES)

The invention is characterized in providing a method of producing a spread multi-filament bundle, which method comprises the steps of: feeding a multi-filament bundle from a yarn supplier such as bobbin, cheese and cone with a restraint of said bundle being drawn back; subjecting the bundle as fed to fluctuation of a tensile force applied thereto alternatively and intermittently between tension and relaxation; passing the bundle moving under such fluctuation through a fluid flowing portion disposed along a moving course of the bundle with the bundle supported in suspension on the fluid flowing portion to put a fluid into contact with the bundle in passage so as to bend the bundle towards a direction to which the fluid flows and to flow said fluid through any adjacent monofilaments of the bundle, thereby, the bundle being widely spread so as to be produced into a spread multi-filament bundle.

(0011)

The invention is characterized in providing a method of producing a spread multi-filament bundle, which method comprises the steps of: feeding a number of multi-filament bundles from a creel provided with a number of yarn suppliers such as bobbin, cheese and cone with a restraint of the respective bundles being drawn back; subjecting the respective bundles to fluctuation of a tensile force applied to the

respective bundles alternatively and intermittently between tension and relaxation; passing the respective bundles moving under such fluctuation through a fluid flowing portion disposed along a moving course of the respective bundles with the respective bundles supported in suspension on the fluid flowing portion to put a fluid into contact with the respective bundles so as to bend the respective bundles towards a direction to which the fluid flows and to flow the fluid through any adjacent monofilaments of the respective bundles, thereby, the respective bundles being widely spread so as to be produced into the respective spread multi-filament bundles.

(0012)

Further, the invention is characterized in providing a method of producing a spread multi-filament bundle, which method comprises the steps of: feeding a number of multi-filament bundles from a creel provided with a number of yarn suppliers such as bobbin, cheese and cone with a restraint of the respective multi-filament bundles being drawn back; subjecting the respective bundles to fluctuation of a tensile force applied to the respective bundles alternatively and intermittently between tension and relaxation; passing the respective bundles moving under such fluctuation through a fluid flowing portion disposed along a moving course of the respective bundles to put a fluid into contact with the respective bundles in passage so as to bend the respective bundles towards a direction to which the fluid flows and to flow the fluid through any adjacent monofilaments of the respective bundles, thereby, the respective bundles being widely spread so as to be produced into a spread multifilament bundles sheet with the side fringe monofilaments of any adjacent bundles tangentially aligned with each other.

(0013)

Further, the invention is characterized in providing a method of producing a spread multi-filament bundle wherein a spread multi-filament bundle as discharged from the fluid flowing portion is subjected to linearly back-and-forth

friction widthwise with regard to a moving course of the spread bundle so as to uniformly distribute in density the monofilaments comprising the spread bundle.

(0014)

Further, the invention is characterized in providing a method of producing a spread multi-filament bundle, which method comprises the steps of: feeding a number of multi-filament bundles from a creel provided with a number of yarn suppliers such as bobbin, cheese and cone with a restraint of the respective bundles being drawn back; subjecting the respective bundles as fed to fluctuation of a tensile force applied to the respective bundles alternatively and intermittently between tension and relaxation; passing the respective bundles moving under such fluctuation through a fluid flowing portion to put a fluid into contact with the respective bundles; overlapping one over another or disposing side by side the respective spread multi-filament bundles; and providing a lineally back-and-forth friction widthwise to a group of the respective spread multi-filament bundles as overlapped or disposed side by side so as to be commingled into a spread multi-filament bundles sheet whose monofilaments are more uniformly distributed in density.

(0015)

Further, the invention is characterized in providing a method of producing a spread multi-filament bundle wherein the tensile force applied to the multi-filament bundle is fluctuated alternatively and intermittently between tension and relaxation by locally and reciprocally pressing the bundle crosswise with regard to a moving course of the bundle.

(0016)

Further, the invention is characterized in providing a method of producing a spread multi-filament bundle wherein a plurality of fluid flowing portions are disposed along a moving course of the bundle, through which portions the bundle is passed in succession so as to be spread in a progressive manner.

(0017)

Further, the invention is characterized in providing a method of producing a spread multi-filament bundle wherein a bending degree secure roller is transversely provided in the fluid flowing portion, under which roller the bundle is passed so as to be put into contact with a fluid, thereby, a predetermined degree by which the bundle bends being secured in such a manner that the minimum degree by which the bundle bends not becoming smaller than the predetermined degree.

(0018)

Further, the invention is characterized in providing a method of producing a spread multi-filament bundle wherein the multi-filament bundle whose monofilaments are bonded together with a sizing agent is passed through the fluid flowing portion with the bundle heated so as to soften the sizing agent, thereby, the bundle being spread.

(0019)

Further, the invention is characterized in providing a method of producing a spread multi-filament bundle wherein a prolonged aperture opened along a moving course of the bundle is segmented into the respective fluid flowing portions, through which portions the bundle is passed in succession so as to be spread in a progressive manner.

(0020)

Further, the invention is characterized in providing a method of producing a spread multi-filament bundle wherein the fluid used in the respective fluid flowing portions is a suction air stream.

(0021)

Further, the invention is characterized in providing an apparatus for producing a spread multi-filament bundle comprising a yarn supplier such as bobbin, cheese and cone around which a multi-filament bundle is wound; a uni-directional multi-filament bundle supply mechanism to unwind the multi-filament bundle under a certain tension from the yarn supplier and to feed the same with a restraint of being drawn back; a fluid flowing spreader comprising a fluid flowing

portion disposed along a moving course of the bundle to put a fluid into contact with the bundle in passage with the bundle in passage supported in suspension thereon so as to bend the bundle towards a direction to which the fluid flows, thereby, the bundle being spread; and a tensile force fluctuation provider to fluctuate the tensile force applied to the multi-filament bundle in passage alternatively between tension and relaxation.

(0022)

Further, the invention is characterized in providing an apparatus for producing a spread multi-filament bundle comprising a creel provided with a number of yarn suppliers around which a multi-filament bundle is wound; a uni-directional multi-filament bundle supply mechanism to unwind the respective bundles from the respective yarn suppliers under a certain tension and feed the same with a restraint of being drawn back; a fluid flowing spreader comprising a fluid flowing portion to put a fluid into contact with the respective bundles in passage crosswise with regard to a moving course of the respective bundles so as to bend the respective bundles towards a direction to which the fluid flows, thereby, the respective multi-filament bundles being spread; and a tensile force fluctuation provider to fluctuate the tensile force applied to the respective bundles alternatively between tension and relaxation.

(0023)

Further, the invention is characterized in providing an apparatus for producing a spread multi-filament bundle wherein the tensile force fluctuation provider comprises a transversely prolonged rod member to locally and reciprocally press the bundle crosswise with regard to a moving course of the bundle.

(0024)

Further, the invention is characterized in providing an apparatus for producing a spread multi-filament bundle wherein a spread multi-filament bundle as discharged from the fluid flowing spreader is subjected to reciprocally back-and-forth

friction widthwise with regard to the moving course of the spread bundle so as to distribute a number of monofilaments comprising the spread bundle uniformly in density.

(0025)

Further, the invention is characterized in providing an apparatus for producing a spread multi-filament bundle wherein a prolonged aperture opened along the moving course of the bundle is segmented into the respective fluid flowing portions of the fluid flowing spreader.

(0026)

Further, the invention is characterized in providing an apparatus for producing a spread multi-filament bundle wherein the fluid flowing spreader comprises the respective fluid flowing portions provided with a suction aperture opened in the same plane along the moving course of the bundle and a suction pump engaged to a discharge side of the respective fluid flowing portions.

(0027)

According to the invention, the multi-filament bundle is subjected to fluctuation of the tensile force applied thereto alternatively between tension and relaxation with the restraint of being drawn back and then subjected to fluidal resistance at the respective fluid flowing portions. Thus, when the tensile force applied to the multi-filament bundle changes from tension mode to relaxation mode, the bundle further bends towards a direction to which the fluid flows so as to facilitate the bundle being widely spread, through the bundle in which condition the air stream flows causing the monofilaments comprising the bundle to move widthwise with their better distribution in density while to flow the fluid through an interstice between any adjacent monofilaments thereof due to the effect brought by the action as described in details in the prior invention by the same inventor entitled 'Method of producing a spread multi-filament sheet and an apparatus used in the same' registered under Japanese Patent No.3064019, thereby, the multi-filament bundle being widely spread.

(0028)

Then, when the tensile force applied to the bundle changes from the relaxation mode to the tension mode, the bundle in passage bends to a small degree in the fluid flowing portion with its spread width maintained as it is and the respective monofilaments aligned in more straight condition.

(0029)

The multi-filament bundle passes through the respective fluid flowing portions with tensile force applied thereto fluctuated repeatedly between tension and relaxation so as to be produced into a widely spread multi-filament bundle whose monofilaments are uniformly distributed in density and aligned in straight condition. To note, the spread width of a multi-filament bundle is affected by the feeding speed thereof, the flowing velocity of a fluid in use, a time-span to fluctuate the tensile force applied to the bundle and so forth, the modifications of which conditions allow the spread width thereof to be fixed in an arbitrary manner or stabilized in a certain level.

(0030)

To note, provided that the duration in which the bundle is being in a mode of tension is prolonged, in which the bundles pass through the fluid flowing portion in a straight manner or without bending therein, the bundle is liable to shift to a condition in which it is converged from that in which it is spread by relaxation, which prevents the bundle from being widely spread in a stable manner. Thus, the time-span between tension mode and relaxation mode to which the bundle is subjected is deeply involved with a length of the fluid flowing portion running along a moving course of the bundle and the feeding speed thereof, so that the time-span between them shall be fixed taking such setting values into considerations in such a manner that the bundle does not pass through the fluid flowing portion in a straight manner.

(0031)

Further, provided that the multi-filament bundle unwound



from a yarn supplier such as bobbin, cheese and cone is subjected to a drawback tension contrary to the direction to which the bundle is fed, the bundle in the mode of relaxation is drawn back to the yarn supplier so as to interrupt the bundle in passage from bending to a predetermined degree in the respective fluid flowing portions. As a result of it, it becomes hard to gain a widely spread multi-filament bundle in a stable manner. Accordingly, by taking such measures as feeding the bundle with the restraint of being drawn back or feeding the bundle with the drawback thereof put under control such that such drawback does not affect the degree by which the bundles bends in the fluid flowing portion, a stable spreading operation is operable at the fluid flowing portion.

(0032)

According to the invention, a multi-filament bundle fed from the yarn supplier is passed through the fluid flowing portion with the tensile force applied thereto and the drawback thereof under control so that there is no difference in tensile force applied to the respective bundles when a number of bundles are laid side by side so as to be spread, on which respective bundles simultaneous spreading operation is performed. A number of bundles respectively are simultaneously subjected to fluctuation of the tensile force applied thereto by the transversely prolonged rod member of simplified structure, which allows the spreading operation to be performed on a number of bundles with facility.

(0033)

Further, a number of multi-filament bundles lined side by side respectively are produced into a spread multi-filament bundles sheet with the fringe side monofilaments of any adjacent bundles tangentially aligned by controlling the spread width of the respective bundles.

(0034)

A linearly back-and-forth friction provided to a spread multi-filament bundle, the tensile force applied to which is fluctuated alternatively between tension and relaxation,

permits a number of monofilaments comprising the spread bundle to be put into a condition in which they are uniformly distributed in density. Especially, the tensile force applied to the spread multi-filament bundle being switched to the relaxation mode facilitates the respective monofilaments thereof moving widthwise, thereby, the spread multi-filament bundle with no damage on its monofilaments such as fibrous cut thereon and its monofilaments uniformly distributed in density being producible.

(0035)

Following that the respective spread multi-filament bundles, the tensile force applied to which fluctuates alternatively between tension and relaxation, are overlapped one over another or disposed side by side so as to be formed into a group of spread multi-filament bundles, to which group a linearly back-and-forth friction is given widthwise so as to be produced into a spread multi-filament bundles sheet whose monofilaments are uniformly distributed in density with the monofilaments of the respective spread bundles commingled with each other.

(0036)

According to the invention, a plurality of fluid flowing portions are arranged along the moving course of the multi-filament bundle, through which respective fluid flowing portions the bundle passes in succession so as to be spread in a progressive manner. Further, the provision of the bending degree secure roller in the respective fluid flowing portions prevents a first degree by which the bundle in passage that is in the tension mode bends from becoming smaller than a second degree by which the bundle in passage bends in contact with the bending degree secure roller, which allows a spread multi-filament bundle with the spread width of the bundle constant to be delivered.

(0037)

According to the invention, a fluid may be gas such as air or liquid such as water, both of which can spread a

multi-filament bundle. However, there is difference in density between gas and liquid in which the latter is larger than the former. Thus, liquid is more capable of spreading the bundle, in which case another process is required to dry up the wetted bundle to prevent the same from widthwise contraction.

#### EFFECT

(0038)

The invention comprises the steps of feeding a multi-filament bundle with the restraint of being drawn back while putting a fluid into contact with the bundle as fed at the fluid flowing portion with the bundle subjected to fluctuation between tension and relaxation so as to be able to widely spread the bundle. The invention also copes with simultaneously spreading a number of multi-filament bundles, which permits a number of spread multi-filament bundles and a spread multi-filament bundles sheet with the fringe side monofilaments of any adjacent bundles tangentially aligned to be produced. Further, the provision of the linearly back-and-forth friction widthwise with regard to a spread multi-filament bundle with the tensile force applied thereto fluctuated alternatively between tension and relaxation allows a spread multi-filament bundle sheet and spread multi-filament bundles whose monofilaments are uniformly distributed in density and free from damage to be produced.

(BEST MODE FOR CARRYING OUT THE INVENTION)

(0039)

Hereinafter, the preferred embodiments of the invention are described in more details with reference to the accompanying drawings.

(0040)

(FIRST EMBODIMENT)

The method of spreading one multi-filament bundle according to the present embodiment is described with reference to Figures 1 through 3.

(0041)

(APPARATUS EXAMPLE 1)

Figures 1 and 2 show an apparatus example 1 used for the method of spreading one multi-filament bundle so as to be produced into a spread multi-filament bundle according to the first embodiment.

(0042)

A multi-filament bundle  $T_m$  unwound from a yarn supplier or bobbin 11 is fed to a fluid flowing spreader 3 under a certain tension and with the restraint of being drawn back by means of a uni-directional multi-filament bundle supply mechanism 2.

(0043)

Such reinforced fibers bundle as carbon fibers bundle, glass fibers bundle, aramid fibers bundle and ceramic fibers bundle as well as such thermoplastic resin fibers bundle as polyethylene fibers, polypropylene fibers, nylon 6 fibers, nylon 66 fibers, nylon 12 fibers, polyethylene terephthalate fibers, polyphenylene sulfide fibers, polyether ether ketone fibers being bundled is adoptable for a multi-filament bundle in use for the invention. As a stranded multi-filament bundle is not feasible for the spreading operation hereof, it is desirable to use a non-strand bundle or an untwisted multi-filament bundle.

(0044)

The uni-directional multi-filament bundle supply mechanism 2 comprises a rotatable positioning roller 21 to support a multi-filament bundle  $T_m$  as drawn out in a fixed position; a pair of rotatable anterior and posterior rollers 22 and 22 to support the bundle  $T_m$  at a downstream side from the roller 21; a rotatable and vertically movable tension providing roller 24 disposed between the roller 21 and the anterior roller 22; an upper position limit sensor 25a and a lower position limit sensor 25b to detect the upper limit position and the lower limit position respectively of the roller 24; a roller 23a to press against the bundle  $T_m$  so as to sandwich the same with the posterior roller 22 and a uni-directionally driving clutch 23b to rotate the roller 23a only to the moving direction of the bundle so as to prevent the same from being

drawn back.

(0045)

The bundle Tm as drawn out is applied an initial tensile force by the roller 24. During the bundle Tm being fed, the roller 24 moves upwards. Upon the upper limit position sensor 25a detecting the roller 24, a yarn supply motor 12 operates to rotate the yarn supplier 11 so as to feed the bundle Tm with a velocity faster than the feeding speed of the bundle, thereby, the roller 24 going downwards and upon the lower limit position sensor 25b detecting the roller 24, the yarn supply motor 12 stops operating. In this manner, the bundle Tm is fed under a certain initial tension.

(0046)

The bundle Tm given a certain tension runs through the support roller 22 and the roller 23a, which roller 23a only rotates to the direction of the moving course of the bundle by means of the uni-directionally driving clutch 23b so that the bundle Tm is fed under a given tension along the moving course thereof, but is not drawn back towards the yarn supplier.

(0047)

Then, reference numeral 3 indicates a fluid flowing spreader. Figures 1 and 2 show an apparatus provided with a fluid flowing portion 31a of suction cavity tube type. The fluid flowing portion 31a is disposed in the same elevation level as the moving course of the bundle Tm, on an entrance side and an exit side of which portion a guide roller 32 to keep the bundle Tm at a given elevation level is provided. A suction pump 34 is engaged to the fluid flowing portion, the operation of which pump with a flow rate adjustment valve 33 regulated as necessary a suction air stream as required for the fluid flowing portion 31a is generated.

(0048)

Then, reference numeral 4 indicates a tensile force fluctuation provider. Upon the rotation of a crank motor 44, a crank arm 43 converts such rotational motion into an up and down motion so as to move a rod 42 up and down. The rod 42 is

disposed between the support rollers 41 and 41 to keep the bundle Tm at a given elevation level. The up and down motion of the rod 42 causes the bundle Tm to be subjected to the fluctuation of the tensile force applied thereto between tension and relaxation. To note, varying the number of revolutions of the crank motor 44 allows the time-span between tension and relaxation for the bundle Tm to be changed.

(0049)

The bundle Tm fed into the fluid flowing spreader 3 is subjected to fluctuation of the tensile force applied thereto between tension and relaxation by means of the tensile force fluctuation provider 4 disposed at a downstream side from the fluid flowing spreader 3, upon the bundle in which condition being subjected to suction air, as shown in Figure 3, the bundle Tm bends towards a direction to which a fluid flows so as to be put into such condition as facilitating the same being widely spread and the suction air flows through any adjacent monofilaments thereof so as to be spread when the tensile force applied to the bundle is switched from the tension mode to the relaxation mode while when the tensile force applied to the bundle is switched from the relaxation mode to the tension mode, the bundle Tm in passage through the fluid flowing portion 31a bends to a small degree with the spread width thereof practically maintained as it is and the respective filaments thereof aligned in more straight manner.

(0050)

A spread multi-filament bundle Ts is taken up by a take-up system 5. The take-up system 5 comprises a take-up roller 51 and a motor 52. According to the rotating speed of the motor 52, the moving speed of the bundle is fixed. To note, As for processes posterior to the take-up system 5, a process where a spread bundle is wound up into a bobbin or reel or that where a matrix material such as resin is impregnated with a spread bundle is added.

(0051)

(SECOND EMBODIMENT)

The method of producing a number of spread multi-filaments bundles according to the present embodiment is described with reference to Figures 4 and 5.

(0052)

(APPARATUS EXAMPLE 2)

Figures 4 and 5 show an apparatus example 2 used for producing a number of spread multi-filament bundles according to the present embodiment.

(0053)

A number of multi-filaments bundles  $T_m$  are unwound from a number of yarn suppliers 11. The respective bundles  $T_m$  as drawn out are fed along the moving course of the respective bundles under a certain tension and with the restraint of being drawn back by means of a uni-directional multi-filament bundle supply mechanism 2. During the respective bundles passing through the guide rollers 26 and 26, they are aligned in parallel and in the same plane so as to be fed into a fluid flowing spreader 3, a tensile force fluctuation provider 4 and a take-up system 5. To note, five yarn suppliers are shown in the drawings, which number can be modified where appropriate.

(0054)

The arrangement of the uni-directional multi-filament supply mechanism 2, the tensile force fluctuation provider 4 and the take-up system 5 respectively is the same as that of the corresponding elements respectively of the apparatus example 2. In order to perform spreading operation on a number of multi-filament bundles  $T_m$ , it is arranged such that as many uni-directional multi-filament supply mechanisms 2 as the yarn suppliers are disposed so as to correspond to the respective bundles  $T_m$ . The tensile force fluctuation provider 4 is provided with a transversely prolonged rod member 42 such that a number of bundles are simultaneously subjected to fluctuation of the tensile force applied thereto between tension and relaxation. The take-up system 5 is provided with a transversely prolonged take-up roller 51 to simultaneously take up a number of spread multi-filament bundles.

(0055)

Reference numeral 3 indicates a fluid flowing spreader of suction cavity tube type. Figures 4 and 5 show an apparatus example 2 provided with three fluid flowing portions 31a, 31b and 31c opened along the moving course of the respective bundles. The respective fluid flowing portions are disposed in the same elevation level as the moving course of the respective bundles, on an entrance side and an exit side of which respective portions a guide roller 32 is provided to keep the respective bundles  $T_m$  in passage in a certain elevation level. A suction pump 34 is engaged to the respective suction cavity tubes, the operation of which pump with a flow rate adjustment valve 33 regulated where appropriate causes a suction air stream with a velocity as required for the respective fluid flowing portions to be generated.

(0056)

The respective bundles  $T_m$  as fed into the fluid flowing spreader 3 are subjected to the fluctuation of the tensile force applied thereto between tension and relaxation by the tensile force fluctuation provider 4 disposed posterior to the spreader 3, upon suction air stream acting on the respective bundles under which fluctuation, the respective bundles bend towards a direction to which the suction air flows to let the suction air flow through any adjacent filaments of the respective bundles so as to be spread. According as the respective bundles proceed from the foremost fluid flowing portion 31a disposed at an upstream side via the fluid flowing portion 31b to the farthest fluid flowing portion 31c, they are gradually spread so as to be produced into the respective spread multi-filament bundles  $T_s$ , which respective spread bundles are taken up by the take-up system 5.

(0057)

(THIRD EMBODIMENT)

The method of producing a spread multi-filament bundles sheet according to the present embodiment is explained with reference to Figure 6 through Figure 12.



(0058)

(APPARATUS EXAMPLE 3)

Figure 6 shows an apparatus example 3 used in the present embodiment.

(0059)

The arrangement of the creel 1, the uni-directional multi-filament supply mechanism 2, the fluid flowing spreader 3, the tensile force fluctuation provider 4 and the take-up system 5 respectively is the same as that of the corresponding elements of the apparatus example 2.

(0060)

In the apparatus example 3, in the same way as the apparatus example 2, the respective bundles  $T_m$  as fed into the fluid flowing spreader 3 are subjected to the suction air stream while subjected to the fluctuation of the tensile force applied thereto between tension and relaxation by the tensile force fluctuation provider 4 disposed posterior to the spreader 3 so as to be spread. In accordance with such setting conditions as the flowing velocity of a fluid in use, the time-span between tension and relaxation and so forth, according as the respective bundles proceed from the foremost fluid flowing portion 31a via the fluid flowing portion 31b to the farthest fluid flowing portion 31c, the respective bundles are spread as widely as required so as to be produced into a spread multi-filament bundles sheet  $T_w$  with the fringe side filaments of any adjacent bundles tangentially aligned with each other after the passage of the farthest fluid flowing portion 31c.

(0061)

(APPARATUS EXAMPLE 4)

Figures 7 and 8 show an apparatus example 4 used in the present embodiment for producing a spread multi-filament bundles sheet.

(0062)

The difference between the apparatus example 4 and that 3 lies in that the former is provided with a widthwise vibrator 6 disposed between the tensile force fluctuation provider 4 and

the take-up system 5, and the other structural arrangement thereof is the same as that of the latter.

(0063)

The widthwise vibrator 6 comprises a vibration roller 62 disposed between support rollers 41 and 61 and a vibration roller 62 disposed between support rollers 61 and 61. The vibration rollers 62 and 62 respectively are made from stainless steel rod whose surface is satin finished. Upon the rotation of a crank motor 65, a crank arm 63 converts such rotational motion into a back-and-forth motion widthwise with regard to the moving course of the respective bundles, which back-and-forth motion is transmitted to the respective vibration rollers through a linkage mechanism 64. Only one pair of vibration rollers are shown, but it may be arranged as many pairs thereof as desired are additionally provided to the downstream side of carriage course. Further, the widthwise vibrator 6 may be disposed in the apparatus examples 1 and 2.

(0064)

Upon spread multi-filament bundles being subjected to the back-and-forth friction widthwise with regard to the moving course of the respective spread bundles by the vibration rollers, a number of filaments comprising the respective spread multi-filament bundles are by far more uniformly distributed in density while the fringe side filaments of any adjacent spread bundles  $T_s$  being tangentially aligned with each other so as to be produced into a spread multi-filament bundles sheet  $T_w$  with the filaments thereof as a whole uniformly distributed in density.

(0065)

(APPARATUS EXAMPLE 5)

Figures 9 and 10 show an apparatus example 5 used in the present embodiment for producing a spread multi-filament bundles sheet.

(0066)

The difference between the apparatus example 5 shown therein and that 4 lies in that the former is provided with a

bending degree secure roller 35 disposed in the respective fluid flowing portions 31a, 31b and 31c, which roller lies crosswise with regard to the moving course of the respective bundles, and the other structural arrangement thereof is the same as that of the latter. To note, the bending degree secure roller may be provided in any one of the apparatus examples 1 through 3. (0067)

According to the apparatus example 5, the respective bundles  $T_m$  are passed under the respective rollers 35, in which condition they are subjected to fluidal resistance. Thus, the degree by which the respective bundles in the tension mode bend does not become smaller than that by which they are put into contact with the roller 35, so that the respective bundles as spread move through the respective fluid flowing portions with the spread width thereof practically maintained to a degree. To note, the elevation level of the roller 35 may be modified where appropriate.

(0068)

#### (APPARATUS EXAMPLE 6)

Figure 11 shows an apparatus example 6 used in the present embodiment for producing a spread multi-filament bundles sheet. (0069)

The difference between the apparatus example 6 and that 5 lies in that the former is provided with a hot fan heater 7 oppositely disposed to the respective fluid flowing portions 31a, 31b and 31c, and the other structural arrangement thereof is the same as that of the latter. This apparatus example 6 is effective for coping with such a case as the filaments of the respective bundles  $T_m$  being bonded together with a resin based sizing agent. The sizing agent is softened by hot air blowing by the heater so as to promote the respective bundles being spread by the action of the suction air at the respective fluid flowing portions. To note, the temperature of hot air depends on the type of the sizing agent, but in case of an epoxy resin based sizing agent, hot air ranging from 80 degrees Centigrade to 150 degrees Centigrade is enough for the agent to be softened.

Further, a far-infrared radiation heater, a high-frequency heater may be adoptable other than the hot fan heater in use for the present apparatus. Then, the heater 7 may be disposed in any one of the apparatuses 1 through 4.

(0070)

(APPARATUS EXAMPLE 7)

Figure 12 shows an apparatus example 7 used in the present embodiment for producing a spread multi-filament bundles sheet.

(0071)

The difference between the apparatus example 7 and that 6 lies in that a prolonged aperture opened along the moving course of the respective bundles is segmented into the respective fluid flowing portions 31a, 31b and 31c with an interval between them, and the other structural arrangement thereof is the same as that of the latter. In comparison with the latter, the former comprises only one flow rate adjustment valve 33 and the sole suction pump 34 so that the manufacturing cost of the apparatus is reduced and the operation thereof is simplified. To note, the arrangement of the apparatus example 7 such that such prolonged aperture is segmented into the respective fluid flowing portions is also adoptable in any one of the apparatus examples 1 through 5.

(0072)

(FOURTH EMBODIMENT)

The method of forming spread multi-filament bundles or a spread multi-filament bundles sheet and then producing a complex spread multi-filament bundles sheet by overlapping one over another such spread multi-filament bundles or such spread multi-filament bundles sheet is explained with reference to Figures 13 through 15.

(0073)

(APPARATUS EXAMPLE 8)

Figure 13 shows an apparatus example 8 used in the present embodiment for producing a complex spread multi-filament bundles sheet.

(0074)

The apparatus example 8 comprises an upper unit and a lower unit respectively provided with a creel 1, a uni-directional multi-filament supply mechanism 2, a fluid flowing spreader 3, a heater 7 and a feeding course switch roller 8 as well as an influx roller 9, a tensile force fluctuation provider 4, a widthwise vibrator 6 and a take-up system 5.

(0075)

A number of multi-filament bundles  $T_m$  are unwound from the respective upper and lower creels 1 and fed to the respective fluid flowing portions under a certain tension and with a restraint of being drawn back by the respective uni-directional multi-filament bundle supply mechanisms 2. The respective bundles  $T_m$  as fed into the respective fluid flowing spreaders 3 are subjected to suction air with the tensile force applied thereto fluctuated between tension and relaxation by the tensile force fluctuation provider 4 disposed posterior to the spreader 3 so as to be gradually spread. Then, the respective bundles being formed into a spread multi-filament bundle or a spread multi-filament bundle sheet, which bundle or sheet moves via the respective feeding course switch rollers 8 towards the influx roller 9. The respective upper and lower spread multi-filament bundles or spread multi-filament bundles sheets are overlapped one over another at the influx roller 9 so as to be formed into a group of spread multi-filament bundles, which group is fed to the widthwise vibrator 6 via the tensile force fluctuation provider 4. The group of spread multi-filament bundles with the tensile force applied to the respective spread bundles fluctuated between tension and relaxation by the tensile force fluctuation provider 4 being subjected to linearly back-and-forth friction widthwise with regard to the moving course of the respective spread bundles, the respective filaments comprising the upper spread multi-filament bundles or spread multi-filament bundles sheet are commingled with those comprising the lower counterparts so as to be produced into a complex spread multi-filament bundles sheet whose filaments are uniformly distributed in density,

which sheet is taken up by the take-up system 5.

(0076)

Figure 14 shows illustrations of overlapping the upper spread multi-filament bundles over the lower counterparts so as to be formed into a group of spread multi-filament bundles, which group is produced into a complex spread multi-filament bundles sheet while Figure 15 shows illustrations of overlapping the upper spread multi-filament bundles sheet over the lower counterpart so as to be formed into a group of spread multi-filaments bundles, which group is produced into a spread multi-filament bundles sheet.

(0077)

Figures 13 through 15 show the case where the respective groups of spread multi-filament bundles in two stages are overlapped one over another so as to be produced into a complex spread multi-filament bundles sheet, but the number of such groups may be three stages or more. Further, the groups overlapped one over another are not necessarily the same type. For instances, the combination between the carbon fibers bundles or the polypropylene fibers bundles, the combination in different type of a reinforced fibers bundle between the carbon fibers bundles and the glass fibers bundles or the carbon fibers bundles and the aramid fibers bundles and the combination between a reinforced fibers bundle and a thermoplastic fibers bundle such as the combination between the carbon fibers bundles and the polypropylene fibers bundles, glass fibers bundles and nylon 6 fibers bundles, which respective combinations are commingled with one another so as to be produced into a complex spread multi-filament bundles sheet.

(EXAMPLES)

(0078)

The concrete examples are explained as follows.

(0079)

(EXAMPLE 1)

The carbon fibers bundle 12K comprising 12,000 monofilaments respectively having 7 $\mu$ m in diameter and marketed

under the trade name of PYROFIL and the item number of TR 50S by Mitsubishi Rayon Co., Ltd. is spread by use of the apparatus example 1 as shown in Figures 1 and 2 provided with a heater 7.

(0080)

The initial tensile force of 40g is applied to a multi-filament bundle Tm by the tension roller 24 and fed to the fluid flowing spreader 3 of suction cavity tube type. The fluid flowing portion 31a has an aperture of 30mm in length opened along the moving course of the bundle, in which fluid flowing portion suction air stream of 20 m/second in an empty condition is generated. A fixed roller having 10 mm in diameter whose surface is satin finished is adopted for the guide roller 32. A hot air of 120 degrees Centigrade is blown over the fluid flowing portion 31a from the heater 7. It is arranged such that the crank motor 44 of the tensile force fluctuation provider 4 revolves at 350 rpm and the pushdown stroke by the rod 42 with regard to the bundle is set at 20 mm and the feeding speed of the bundle is set at 10 m/minute by the take-up system 5.

(0081)

The carbon fibers bundle 12K whose initial width is 5 mm and whose initial thickness is 0.15 mm is formed into a spread multi-filament bundle Ts having 20 mm in width and 0.04 mm in thickness, the filaments of which spread bundle are stable in width and uniformly distributed in density.

(0082)

(EXAMPLE 2)

Five carbon fibers bundles are simultaneously spread by use of the apparatus example 2 provided in addition with the bending degree secure roller 35 and the heater 7 so as to be produced into as many spread multi-filament bundles. The carbon fibers bundle 6K comprising 6000 monofilaments respectively having an elastic modulus of 540 Gpa, in comparison with which a generally used carbon fiber has 240 Gpa in elastic modulus, and marketed under the trade name of TORAYCA and the item number of M55J by Toray co., Ltd., is adopted for a sample material.

(0083)

Five yarn suppliers 11 are disposed such that five fibers bundles  $T_m$  are lined side by side with 10 mm spaced apart from each other, to which respective bundles the initial tensile force of 25g is applied and which bundles are fed to the fluid flowing spreader 3 of suction cavity tube type. The respective fluid flowing portions 31a, 31b and 31c have 50 mm in width and an aperture of 30 mm in length opened along the moving course of the respective bundles, in which respective portions suction air stream of 20 m/second in an empty condition is generated. A fixed roller having 10 mm in diameter whose surface is satin finished is adopted for the guide roller 32. A bending degree secure roller 35 having 10 mm in diameter is internally disposed at the depth of 10 mm of the respective fluid flowing portions from the level where the respective bundles are supported in suspension, for which roller a fixed roller whose surface is satin finished is adopted. A hot air of 120 degrees Centigrade is blown over the respective fluid flowing portions from the heater 7. The crank motor 44 of the tensile force fluctuation provider 4 revolves at 350 rpm and the pushdown stroke by the rod 42 with regard to the respective bundles is set at 20 mm while the feeding speed of the respective bundles is set at 10 m/second by the take-up system 5.

(0084)

The respective carbon fibers bundles 6K whose initial width is 1 mm and whose initial thickness is 0.2 mm are formed into the respective spread fibers bundle  $T_s$  having 8 mm in width and 0.03 mm in thickness. Further, in spite of the fact that the carbon fibers bundle in use is of high elastic modulus, the filaments comprising the respective fibers bundles are uniformly distributed in density and almost free from fibrous cut.

(0085)

(EXAMPLE 3)

Sixteen carbon fibers bundles are simultaneously spread by use of the apparatus example 6 as shown in Figure 11 so as



to be produced into a spread fibers bundles sheet. A carbon fibers bundle 12K comprising 12,000 monofilaments respectively having 7 $\mu$ m in diameter and marketed under the trade name of PYROFIL and the item number of TR50S by Mitsubishi Rayon Co., Ltd., is adopted for a sample material.

(0086)

Sixteen yarn suppliers are disposed such that as many fibers bundles T<sub>m</sub> are lined side by side with an interval of 20 mm between them, to which respective bundles the initial tensile force of 40g is applied by the respective tension roller 24 and which respective bundles are fed to the fluid flowing spreader 3 having three suction cavity tubes. The respective fluid flowing portions 31a, 31b and 31c have 320 mm in width and an aperture of 30 mm in length opened along the moving course of the respective bundles, in which respective portions suction air stream of 25 m/second in an empty condition is generated. A bending degree secure roller having 10 mm in diameter is internally disposed at the depth of 10 mm of the respective fluid flowing portions from the level where the respective bundles are suspended, for which roller a fixed roller whose surface is satin finished is adopted. A hot air of 120 degrees Centigrade is blown over the respective fluid flowing portions from the heater 7. The crank motor 44 of the tensile force fluctuation provider 4 revolves at 350 rpm and the pushdown stroke by the rod 42 with regard to the respective bundles is set at 20 mm. Further, the widthwise vibrator 6 is provided with two vibration rollers 62 and 62 whose surface is satin finished, the crank motor 65 of which vibrator revolves at 200 rpm and whose vibration rollers 62 and 62 move back and forth by 4mm so as to be provided widthwise back-and-forth friction on a spread fibers bundles sheet. The feeding speed of the respective bundles is set at 10 m/minute.

(0087)

The respective carbon fibers bundles 12K whose initial width is 5 mm and whose initial thickness is 0.15 mm are formed into the respective spread fibers bundles T<sub>s</sub> having 20 mm in

width so as to be produced into a spread fibers bundles sheet Tw having 320 mm in width and 0.04 mm in thickness with the fringe side filaments of any adjacent spread bundles Ts tangentially aligned and the filaments thereof as a whole uniformly distributed in density.

(0088)

(EXAMPLE 4)

Sixteen carbon fibers bundles are simultaneously spread by use of the apparatus example 7 so as to be produced into a spread fibers bundles sheet. A carbon fibers bundle 12K comprising 12,000 monofilaments respectively having 7 $\mu$ m in diameter and marketed under the trade name of PYROFIL and the item number of TR50S by Mitsubishi Rayon Co., Ltd., is adopted for a sample material.

(0089)

Sixteen yarn suppliers 11 are disposed such that as many fibers bundles are lined side by side with an interval of 20 mm between them. The initial tensile force of 40g is applied to the respective fibers bundles by the respective tension rollers 24. A prolonged aperture opened along the moving course of the respective fibers bundles is segmented into the respective fluid flowing portions 31a, 31b and 31c comprising a fluid flowing spreader 3 of suction cavity tube type, which aperture has 320 mm in width and is segmented into the respective fluid flowing portions by 30 mm in length dimensioned along the moving course of the respective fibers bundles. For a guide roller 32, a fixed roller having 10 mm in diameter whose surface is satin finished is adopted. A suction pump 34 is operated with a flow rate adjustment valve 33 regulated so as to generate suction air stream of 25 m/second in an empty condition. A bending degree secure roller having 10 mm in diameter is internally disposed at the depth of 10 mm of the respective fluid flowing portions from the level where the respective fibers bundles are supported in suspension, for which roller a fixed roller whose surface is satin finished is adopted. A hot air of 120 degrees Centigrade is blown over the respective fluid

flowing portions from a heater 7. It is arranged such that the crank motor 44 of the tensile force fluctuation provider 4 revolves at 350 rpm and the pushdown stroke by the rod 42 with regard to the respective bundles is set at 20mm. Further, a widthwise vibration provider 6 is provided with two vibration rollers 62 and 62 whose surfaces are stain finished to provide a widthwise back-and-forth friction with regard to a spread fibers bundles sheet with a crank motor 65 revolving at 200 rpm and moving back and forth widthwise by 4 mm with regard thereto. The feeding speed of the respective fibers bundles is set at 10 m/minute by the take-up system 5.

(0090)

The respective carbon fibers bundles 12K whose initial width is 5 mm and whose initial thickness is 0.15 mm are formed into the respective spread fibers bundles Ts having 20 mm in width, the fringe side monofilaments of which adjacent bundles are tangentially aligned so as to be produced into a spread fibers bundles sheet Tw having 320 mm in width and 0.04 mm in thickness with the monofilaments thereof as a whole uniformly distributed in density.

(0091)

(EXAMPLE 5)

Sixteen carbon fibers bundles are simultaneously spread by use of an apparatus example 8 as shown in Figure 13 so as to produce a spread fibers bundles sheet. For a carbon fibers bundle, the carbon fibers bundle 12K having 12,000 monofilaments respectively having 7 $\mu$ m in diameter bundled is adopted and marketed under the trade name and item number in this order of 'RYROFIL TR50S' by Mitsubishi Rayon Co., Ltd. is adopted.

(0092)

Eight yarn suppliers 11 are mounted onto an upper creel 1 and as many yarn suppliers are mounted onto a lower creel 1 such that the respective fibers bundles Tm fed from the upper and lower creels 1 respectively are lined side by side with an interval of 40 mm between them. To note, the respective fibers

bundles T<sub>m</sub> fed from the upper and the lower creels respectively run with the displacement of 20 mm widthwise from each other. The initial tensile force of 40g is applied to the respective bundles T<sub>m</sub> by the respective tension rollers 24, which bundles are fed into the corresponding upper and lower fluid flowing spreader 3 provided with three suction cavity tubes. The respective upper and lower fluid flowing portions 31a, 31b and 31c have 320 mm in width and an aperture of 40 mm in length opened along the moving course of the respective bundles, in which portions respectively suction air flow of 25 m/second is generated in an empty condition. A bending degree secure roller having 10 mm in diameter is internally disposed at the depth of 10 mm of the respective portions from the level where the respective bundles are supported in suspension, for which roller a fixed roller whose surface is satin finished is adopted. Then, a hot air of 120 degrees Centigrade is blown over the respective fluid flowing portions from the heater 7. It is arranged such that the crank motor 44 of the tension fluctuation provider 4 revolves at 300 rpm and the pushdown stroke by the rod 42 with regard to the respective bundles is set at 20 mm. Further, the widthwise vibrator 6 is provided with two vibration rollers 62 and 62 whose surfaces are satin finished to provide back-and-forth friction widthwise with regard to a combined spread fibers bundles sheets with a crank motor 65 revolving at 200 rpm and moving back and forth by 4 mm. The feeding speed of the respective bundles is set at 10 m/minute by the take-up system 5.

(0093)

The respective upper and lower carbon fibers bundles 12K whose initial width is 5 mm and whose initial thickness is 0.15 mm are formed into spread fibers bundles T<sub>s</sub> having 40 mm in width, which respective bundles are discharged in the form of a spread fibers bundles sheet from the upper and lower fluid flowing spreaders 3 respectively, which upper and lower sheets are overlapped one over another by an influx roller 9 via the respective feeding course switch rollers 8. Thereafter, the

sheets as overlapped are subjected to vibration widthwise with regard to their moving course by the widthwise back-and-forth vibrator 6 so as to be produced into a complex spread fibers bundles sheet Tw having 320 mm in width and 0.04 mm in thickness with the monofilaments thereof as a whole uniformly distributed in density.

(BRIEF DESCRIPTION OF THE DRAWINGS)

Figure 1 is a side view of an apparatus example 1 to show one fibers bundle spread by the apparatus according to the first embodiment.

Figure 2 is a plan view of the apparatus example 1.

Figure 3 comprises illustrations to show the state where the fibers bundle is in the fluid flowing portion while the tensile force applied to the fibers bundle ahead is subjected to tension or relaxation by the tensile force fluctuation provider.

Figure 4 is a side view of an apparatus example 2 to show a number of fibers bundles spread so as to be formed into as many spread fibers bundles according to the second embodiment.

Figure 5 is a plan view of the apparatus example 2 as shown in Figure 4.

Figure 6 is a plan view of an apparatus example 3 to show a number of fibers bundles spread so as to be formed into a spread fibers bundles sheet according to the third embodiment.

Figure 7 is a side view of an apparatus example 4 to show a number of fibers bundles spread so as to be formed into a spread fibers bundles sheet according to the third embodiment.

Figure 8 is a plan view of the apparatus example 4 as shown in Figure 7.

Figure 9 is a side view of an apparatus example 5 to show a number of fibers bundles spread so as to be formed into a spread fibers bundles sheet according to the third embodiment.

Figure 10 is a plan view of the apparatus example 5 as shown in Figure 9.

Figure 11 is a side view of an apparatus example 6 to show a number of fibers bundles spread so as to be formed into a spread

fibers bundles sheet according to the third embodiment.

Figure 12 is a side view of an apparatus example 7 to show a number of fibers bundles spread so as to be formed into a spread fibers bundles sheet according to the third embodiment.

Figure 13 is a side view of an apparatus example 8 to show a number of fibers bundles spread to be formed into spread fibers bundles or a spread fibers bundles sheet and overlapped such bundles or sheets one over another so as to be produced into a complex spread fibers bundles sheet according to the fourth embodiment.

Figure 14 comprises illustrations to show the upper and lower spread fibers bundles overlapped one over another so as to be produced into a complex spread fibers bundles sheet according to the fourth embodiment.

Figure 15 comprises illustrations to show the upper and lower spread fibers sheets overlapped one over another so as to be produced into a complex spread fibers bundles sheet according to the fourth embodiment.

#### ABSTRACT

Method of widely spreading an arbitrary number of fibers bundles with facility and high speed with the monofilaments thereof uniformly distributed in density and free from any fluffs and an apparatus used in the same are provided herein.

The method comprises the steps of feeding a fibers bundle with the restraint of being drawn back; subjecting the bundle to fluctuation of the tensile force applied thereto alternatively between tension and relaxation; passing the bundle moving under such fluctuation through the fluid flowing portion disposed along the moving course of the bundle with the bundle supported in suspension thereon to be subjected to fluidal resistance so as to bend the bundle in passage towards a direction to which a fluid flows with the fluid flowing through any adjacent filaments thereof, thereby, the bundle being spread widthwise with regard to the moving course thereof.